Source Selection for Laser Welding

Just 15 years ago, choosing a laser source for welding was pretty straightforward: select pulsed neodymium-doped yttrium aluminum garnet (Nd:YAG) lasers for spot or micro seam welding, and carbon dioxide (CO_2) or continuous wave (CW) Nd:YAG lasers for penetration or seam welding. Now, however, laser welding is gaining traction in many industries, and, as the marketplace expands, so does the choice of available laser sources.

Today manufacturers can choose from fiber, pulsed Nd:YAG, diode, disk, and CO_2 lasers. (As CW Nd:YAG has been superseded by fiber and disk laser technologies, it is not discussed in this article). When choosing among laser sources, it is essential to understand a variety of application-specific factors, including material, joint geometry, weld penetration, speed, fit-up tolerances, integration requirements and, of course, budget. Each source has a particular set of characteristics that align with weld requirements, although there may also be overlap in certain cases.

LASER SOURCES AVAILABLE

Lasers are described either by the type or shape of the amplification medium. For example, "fiber" lasers are so named because the laser is created and amplified within a doped silicon fiber. Similarly, an "Nd:YAG" laser refers to the crystal used as the amplifying medium. The most commonly used lasers for industrial applications are listed and described in **Table 1**.

Laser type	Type of welder	Penetration limit	Beam delivery	Maximum aspect ratio (weld depth / width)	Typical Power range (kW)	Comments
Pulsed Nd:YAG	Micro	0.05-inch	Fiber	1	.025-0.6 (0.25-10 peak power)	Micro welder for all weld types
Pulsed fiber (QCW)	Micro	0.07-inch	Fiber	3	0.15 – 0.9 (1.5 – 9 peak power)	Micro welder for many weld types
CO_2	Macro	1-inch	Mirrors	10	1 – 10	Traditional workhorse industrial macro welder
Disk	Macro	0.5-inch	Fiber	10	1 – 10	Direct macro welding competition to CO_2 and fiber
Diode	Macro	0.3-inch	Fiber	5	0.5 – 6	New welding laser developing applications in large tolerance welding and macro welding.
CW Fiber	Micro & Macro	1-inch+	Fiber	20	0.2 – 10	Highly flexible source. For macro applications direct competition to CO_2 and disk.

Table 1 – Laser sources, typical industrial power ranges and performance capabilities

CHOOSING THE RIGHT SOURCE BY PENETRATION CATEGORIES

There are numerous industrial laser welding applications. For ease of discussion, these have been divided into two penetration categories: under 0.03-inch utilizing less than 1kW laser average power, and less than 0.03-inch utilizing more than 1kW average laser power. Each section describes some of the key considerations. There is no doubt that more than one laser source can be used to make the weld, but production implementation, weld performance, and budget considerations usually narrow the choice to one or two laser sources. From that point, the choice may be made based on many other factors, including pre-sale sample quality, geography, post-sales support, and system integrator preferences.

UNDER 0.03-INCH WELD PENETRATION AND 1KW LASER POWER (MICRO WELDING)

The welding categories for this penetration segment are spot welds, temperature sensitive seam welds and high speed seam welding. The lasers suited to this category are pulsed Nd:YAG, pulsed and CW fiber laser, and diode. Because the disk laser has a minimum power level of 1kW, it is not considered a primary laser source for this category.

Table 2 provides a quick reference guide for laser selection for < 0.03-inch penetration and weld width requirement.

Weld	< 75 micron weld width	>75 micron weld width
Spot weld	Pulsed and CW fiber	Pulsed fiber, pulsed Nd:YAG
Heat sensitive seam weld	Pulsed and CW fiber	Pulsed fiber, pulsed Nd:YAG
High speed seam weld	CW fiber	CW fiber, diode

Table 2 – Laser selection reference guide

The three key selection criteria are the final weld width, heat input and the speed of the weld. The pulsed Nd:YAG laser, which features high peak power, was specifically designed for welding applications with weld widths of 200-700 microns, which covers a large percentage of all welding applications.

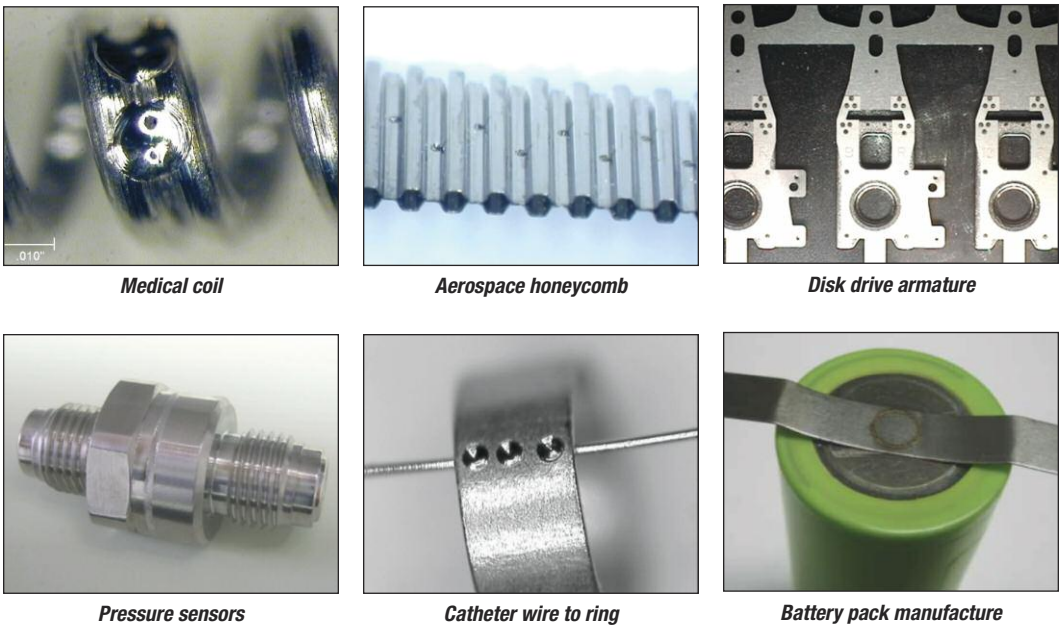
Consumer electronics, battery, and medical applications require small weld widths and/or high speed welding, which is particularly suited to fiber lasers. The diode laser in this category is only usable with high speed welds and larger weld widths. Likely fit-up tolerances of production parts needs to be carefully considered and factored into the laser source selection process – it can be easy to get a little penetration and weld speed greedy at the expense of part fit-up accommodation using the fiber lasers! The welds in this category require intimate contact with the most demanding fit-up tolerances. Therefore the laser source must accommodate tolerances in a production environment.

There is some additional navigating required to fully understand which laser source to select, particularly when choosing between the fiber and pulsed Nd:YAG lasers. Although there are processing differences and nuances to be discovered at an application testing level, there are two

main differences between the options that are important commercial considerations: consumables and service.

Fiber lasers have essentially no consumables. However, if the laser has a problem it typically must be returned to the manufacturer for repair. In contrast, the pulsed Nd:YAG laser has flashlamp consumables that need to be replaced between half a million shots and 300 million shots, depending upon the application – seam welding increases lamp lifetime, occasional spot welding and operating at maximum pulse energy reduces lifetime However, the Nd:YAG lasers are field-repairable, with a design that allows any and every component to be replaced.

Figure 1 shows a variety of laser micro welding applications, in this <0.03-inch penetration category.



Medical coil | *Aerospace honeycomb* | *Disk drive armature*

Pressure sensors | *Catheter wire to ring* | *Battery pack manufacture*

Figure 1 – Laser micro welding applications

GREATER THAN 0.03-INCH WELD PENETRATION AND 1KW LASER POWER

Generally, for penetration seam welding, the CO_2, fiber, diode, and disk lasers are appropriate choices for this weld penetration category. The CO_2 laser has the largest install base with much longer laser OEM and user experience, though fiber and disk are and have been moving into this market. The reasons for the increase in take up of fiber and disk over CO_2 lasers include the fact that they are smaller compact lasers, fiber delivery for integration ease, better wall plug efficiency, and lower maintenance costs. The diode laser is at present the relative newcomer in this category, offering the best wall plug efficiency, potential wavelength optimization for aluminum, and a complete insensitivity to back reflections from the workpiece.

Welding performance in terms of power range choice, flexibility, and configurability favor the fiber and disk lasers. Between these two, the welding performance is probably edged by the fiber laser.

The integration ease and optical flexibility of the fiber, disk, and diode lasers is a big plus factor and has most laser system builders already convinced. It is becoming increasingly difficult to justify even looking at a CO_2 laser when this is factored in from a cost and ROI perspective. It's also worth noting that between the disk and fiber lasers a far greater number of integrators use fiber lasers, which ultimately offers more choice for the end user – a key factor in the decision.

Figure 2 shows a variety of examples of high power CW laser welding.

Automotive steering column

Automotive crank case

Large battery can seam seal and tab welding

Figure 2 – Examples of high power CW laser welding

LASER SELECTION REQUIRES THOROUGH UNDERSTANDING OF APPLICATION SUITABILITY

There are a number of laser sources available for laser micro and macro welding, and each has specific performance characteristics that align with certain application categories. During the selection process it is important to keep in mind that welding is a balance among such factors as penetration, speed, weld stability, and accommodation of production part fit-up and tolerances. The end user should have sufficient understanding of which lasers are best suited to their welding application. This understanding can be self-acquired or through partnering with experienced laser system integrators and laser OEMs. Ideally this same company would also be the system integrator, ensuring that system optimization and configuration is completed with a full understanding of the process.